Origin, Propagation, and Fate of Near Shore Internal Tides and of Internal Bores; Numerical Modeling and Field Verification

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OBJECTIVES

(1) Construct descriptions of internal tides and high frequency internal waves over the slope and shelf with longer time series and with much finer spatial and time resolution than previous descriptions.
(2) Use these descriptions to understand where the fields are generated and damped, in particular the extent to which they are nearshore expressions of motions in the adjacent deep water.

APPROACH

Analysis of the data set obtained during the 1996-97 summer and autumn deployments of ADCP and T-logger internal wave antennas of Mission Beach, CA (figure 1) was the principle activity during the present reporting period. Ph.D. student Jim Lerczak had primary responsibility for this analysis.

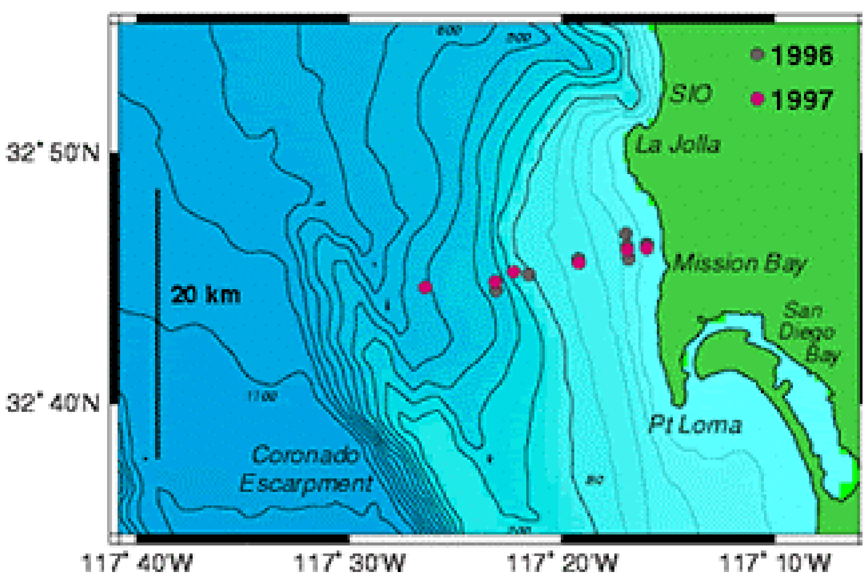

Figure 1. Internal Waves on Continental Margin (IWAVES) site. Empty circles mark summer-1996 moorings, black circles summer-1997 moorings, gray circles summer-1996/1997 moorings. Depths in meters.

WORK COMPLETED

During the present reporting period Jim Lerczak completed his Ph.D. thesis. The principle conclusions of the thesis are summarized below, grouped by frequency band.

RESULTS

Diurnal Band (1/36 to 1/18 cph). Diurnal-band internal waves were surface enhanced, and phase lines propagated upward, suggesting a downward energy flux and a surface source, the remarkably monochromatic diurnal local seabreeze, for the motions. While the diurnal currents were energetic, they were intermittent in time. Much of this intermittency was due to changes in the background vorticity field (figure 2) as in Balmforth and Young, 1999.

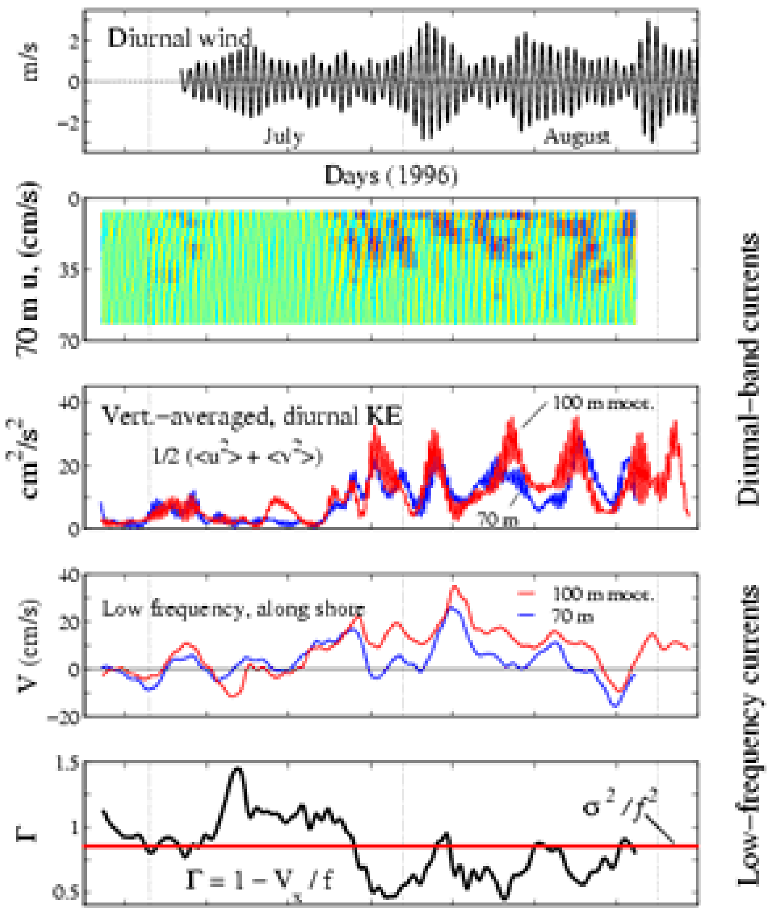

Figure 2. All quantities plotted against time during summer 1996. From top: (i) diurnal band local on-offshore wind, (ii) diurnal band on-offshore flow at the 70 m mooring, (iii) vertically averaged KE at 70 m and 100 m mooring (note similarity of series at these two moorings), (iv) low frequency (2 day running mean) alongshore velocity at 70 m and 100 m mooring (note increase in dV/dx at about yearday 210), (v) effective Coriolis parameter f-dV/dx, scaled by f (diurnal motions, whose frequency relative to f is shown by the solid horizontal line, are propagating when their frequency exceeds the effective Coriolis parameter and evanescent when their frequency falls below the effective Coriolis parameter). Note the correspondence between the times (days 210 -240) of strong diurnal currents (ii) and the times when the diurnal frequency exceeds the effective Coriolis parameter (v).

Semidiurnal Band (1/14.5 to 1/11 cph) Internal Tides. Semidiurnal-band currents on the slope were predominantly in the along isobath direction, suggesting that energy propagated in the along isobath direction. Currents were bottom-intensified and consonant with a northward-propagating, bottom-trapped wave, trapped on the slope. Semidiurnal currents on the shelf had a unique structure not reported elsewhere in the literature. Semidiurnal currents near the surface were clockwise-circularly polarized, while currents near the bottom were linearly polarized in the cross-isobath direction.

Vertically-averaged semidiurnal currents on the shelf did not behave like the surface tide. While they were oriented in the along-isobath direction, their amplitude and phase were not stable over time, unlike the surface tide. These motions may be the shelf response to larger scale slope/shelf motions such as Kelvin waves (Dale and Sherwin, 1996) or bottom-trapped waves (Ou and Beardsley, 1980).

Residual, semidiurnal-band currents (currents remaining after vertical average was removed) behaved very much like onshore-propagating, partially-reflected, mode-one internal waves. The reflection coefficient varied seasonally, being highest in the summer and lower in the fall.

The square coherencies between the semidiurnal-band currents and the surface tide were as high as they could be, given the observed degree of smearing out of tidal lines in the currents (figure 3).

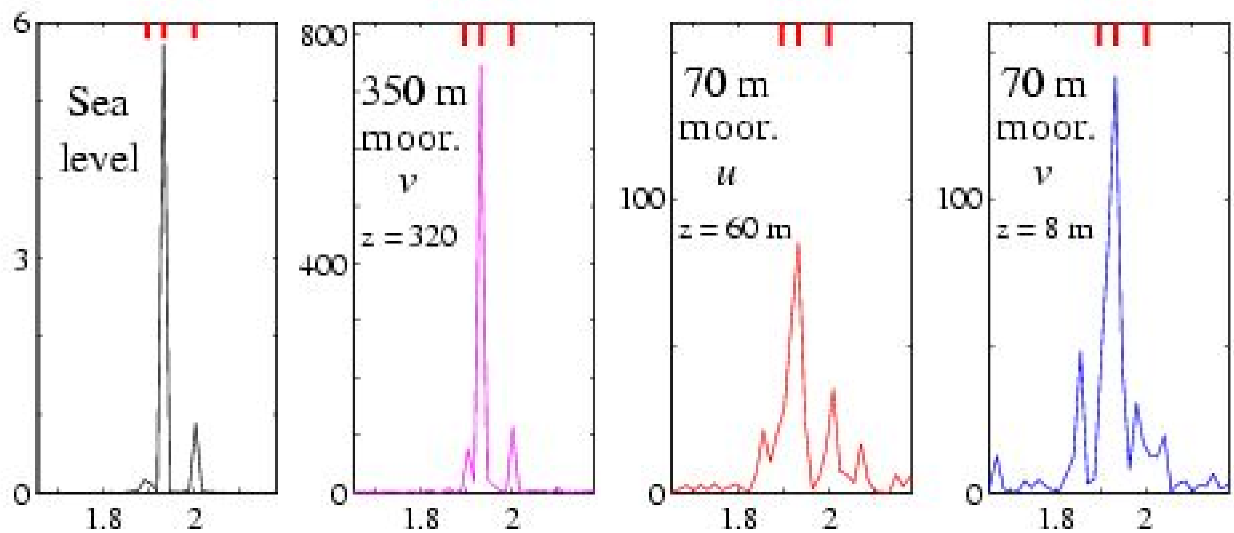

Figure 3a. Spectra (various scales) of sealevel, alongshore current (v) at a depth of 320 m at the 350 m mooring, cross shore (u) currents at a depth of 60 m at the 70 m mooring, and alongshore current (v) at a depth of 8 m at the 70 m mooring. Note the broadening of the current spectra relative to the sealevel spectrum.

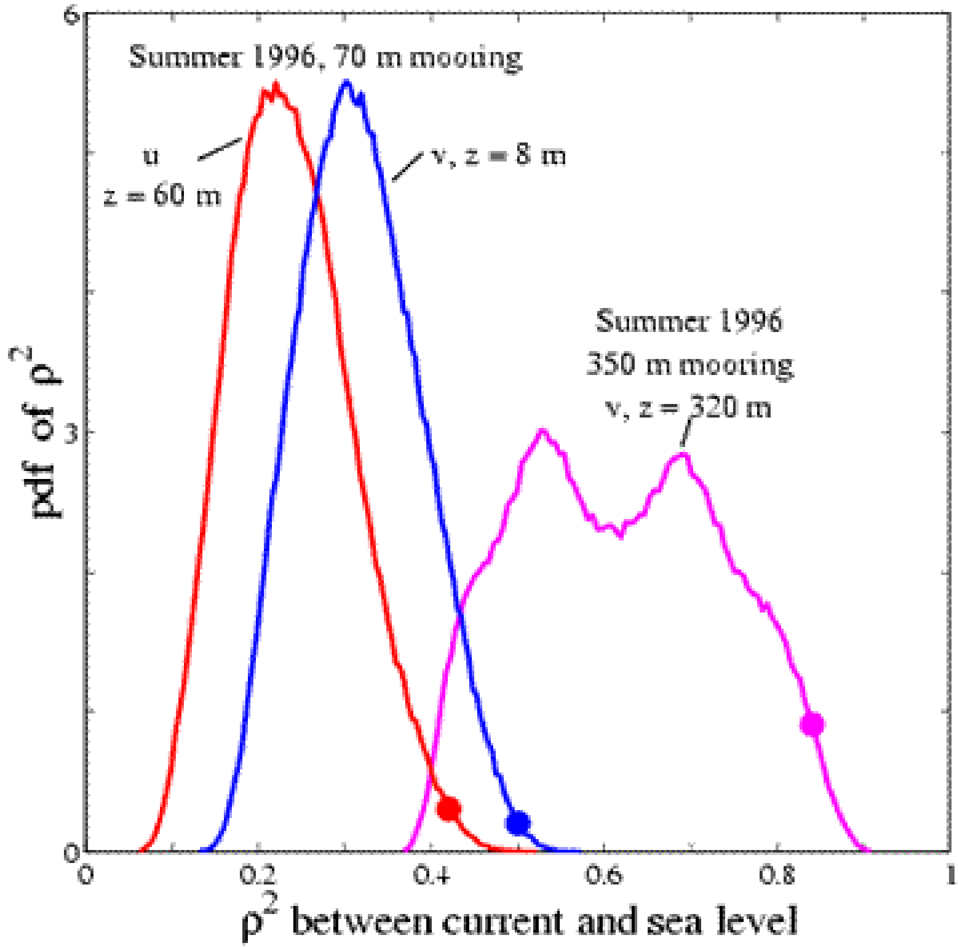

Figure 3b. Probability distribution functions (pdfs) for the square coherence between the sealevel record and an ensemble of synthetic current records having the observed power spectra but random phases of individual spectral components. The solid circles show the squared coherence between the sealevel record and the observed current records; the tendency of the coherence between observed currents and sealevel to lie on the upper tails of the pdfs characterizes nearly all the IWAVES semidiurnal currents.

High-frequency (1 cph to 1/2 cp min) Internal Waves. The vertical structure of the high-frequency internal waves was consistent with onshore-propagating, mode-one internal waves. However, the vertical structure was frequency dependent in a way not obviously explained by either linear or weakly-nonlinear theory. The phase speed of these waves decreased as the waves shoaled (propagated into shallow water) in a manner consistent with linear theory.

The high frequency waves were well developed and traceable shoreward from the 30 mooring to the 15 m mooring but, remarkably, they rarely had high frequency predecessors further offshore at the 70 and 120 m moorings (figure 4). The high frequency waves were highly dissipative, losing approximately 75% of their energy while propagating across the 1.5 km cross shore distance separating the 30 m mooring from the 15 m mooring.

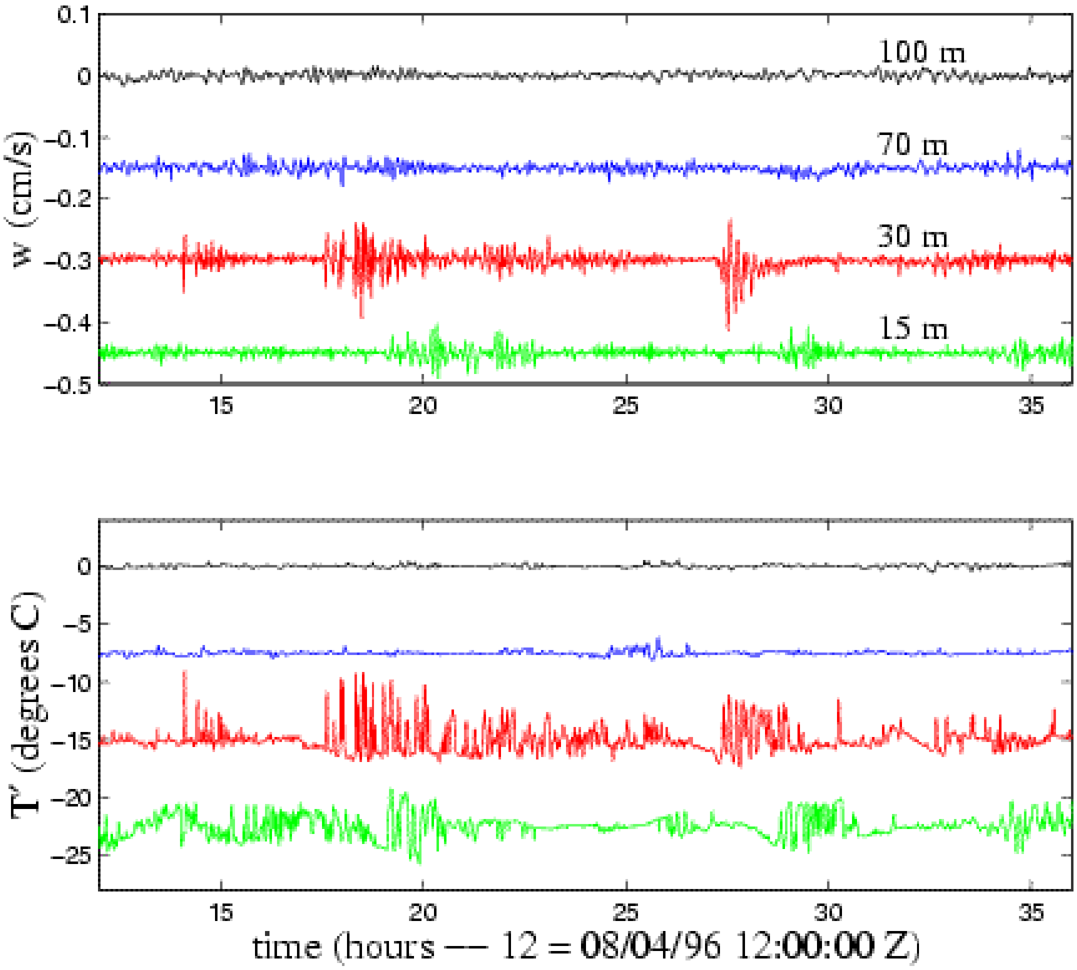

Figure 4. Top panel: High frequency mid depth vertical velocities at 100 m, 70 m, 30 m and 15 m moorings. Bottom panel: High frequency mid depth temperature fluctuations at 100 m, 70 m, 30 m and 15 m moorings. Events clearly propagating from the 30 m mooring to the 15 m mooring have no predecessors at the deeper (100 m, 70 m) moorings. The amplitude of such events decays visibly from the 30 m mooring to the 15 m mooring.

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Dale, A. C. and Sherwin, T. J., 1996: The extension of baroclinic coastal-trapped wave theory to superinertial frequencies. Journal of Physical Oceanography, 26, 2305-2315.

Ou, H.-W. and Beardsley, R. C.,1980: On the propagation of free topographic Rossby waves near continental margins, Part 2. Journal of Physical Oceanography, 10, 1323-1339.

PUBLICATIONS

Lerczak, J. A., 2000: Internal waves on the Southern California Shelf. Ph.D. thesis, University of California, San Diego, 547 p.